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EVALUATION OF ERTS-1 DATA APPLICATIONS TO GEOLOGIC MAPPING, STRUCTURAL ANALYSIS AND MINERAL RESOURCE INVENTORY OF SOUTH AMERICA WITH SPECIAL EMPHASIS ON THE ANDES MOUNTAIN REGION

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2 February 1974

Type I Progress Report for Period 1 November - December 31, 1973

(E75-10118) EVALUATION OF ERTS-1 DATA APPLICATIONS TO GEOLOGIC MAPPING, STRUCTURAL ANALYSIS AND MINERAL RESOURCE INVENTORY OF SOUTH AMERICA WITH SPECIAL EMPHASIS ON THE ANDES MOUNTAIN REGION Bimonthly (Geological G3/43 N75-16039 Unclas 00118

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Greenbelt, Maryland 20771

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Type I Progress Report
ERTS-1

a) Title: Geologic Mapping, Structural Analysis and Mineral Resource Inventory of South America
ERTS-A Proposal No. SR-E189

b) GSFC ID No. of P. I.: IN-012

c) Statement and explanation of any problems that are impeding progress of the investigation

The move of our offices from downtown Washington, D. C., to Reston, Virginia, took place at the end of November. This involved about a two-week interruption of data analysis. On the other hand, the move to offices which are in the Special Mapping Center helped speed up the processing of the LaPaz Mosaic, which is now complete. Ozalid copies are provided as an addendum to this report. Hard copies, costing $7.00 each, can be obtained from the USGS Topographic Division, Special Mapping Center, Reston, Virginia.

Copies of the mosaic are being sent to cooperating investigators in Peru, Chile, and Bolivia.

d) Discussion of the accomplishments during the reporting period and those planned for the next reporting period

1) Completion of the LaPaz Mosaic, using 22 band 6 images has been accomplished. Interpretive overlays are now underway. A tectolinear overlay will be the first to be completed. This will be followed by a mine location map showing type of deposit and will be used as a base for a new metallogenetic province map of the area. Hopefully, the two sources of information (the tectolinear and ore deposit map) will provide new insight on potential areas for exploration.

2) The project office was visited by Dr. Jose Corvalan, the new Director of Instituto de Investigaciones Geologicas of Chile. Dr. Corvalan is an old friend of the USGS having received his Doctorate under USAID/USGS sponsorship from Stanford University. He is very anxious to bring Chile into this ERTS-1 experiment and has made suggestions for the ERTS-B Program in Chile. This interest is expressed and documented in a letter dated January 29, 1974, attached to this report (Attachment A). He will develop a more detailed modification to the ERTS-B Proposal within guidelines provided by this office.

3) In November W. D. Carter presented a 30-minute verbal status report to the GSFC Geology Review Committee under the chairmanship of Dr. Nicholas Short. No written comments of that review have been received.

4) In December W. D. Carter presented an English translation of a report entitled, "Earth Resources Technology Satellite Data Collection Project, ERTS - Bolivia," by Dr. Carlos Brockmann, Principal Investigator for Bolivia, at the Third ERTS-1 Symposium at the Statler Hilton Hotel, Washington, D. C. Brockmann was unable to attend the meeting and asked that Carter translate and present the report for him. The report showed that excellent progress has been made by the Bolivian team in the fields of geology, hydrology, soils and forest mapping and petroleum exploration. It will be published in the Proceedings of the Third ERTS Symposium.

e) Discussion of significant scientific results and their relationship to practical applications or operational problems (Abstract)

Analysis of the LaPaz Mosaic is proceeding well. An abstract has been prepared for submittal as a contributed paper through the National Academy of Science to the COSPAR Plenary Meeting to be held in June 1974 in Sao Paulo, Brazil. See Attachment B.

f) A listing of published articles and/or papers, preprints, in-house reports, abstracts of talks, that were released during the reporting period

Carter, W. D., 1973, Use of Space Shuttle for Earth Resource Mapping, Inventory and Evaluation: in Space Shuttle Payloads, Vol. 30, Science and Technology Series of the Amer. Astronautical Soc., p. 143-153. (See Attachment C)

Carter, W. D., (in press) Tectolinear Interpretation of an ERTS-1 Mosaic, LaPaz Area, Southwest Bolivia, Southeast Peru and Northern Chile: Abstract for presentation at 17th Plenary Meeting of COSPAR, Sao Paulo, Brazil, June 1974. (Attachment B)

Ericksen, George E., 1973, A resume of Seismicity and Tectonics in the Andean Region: Unpublished report presented to the Japan/U. S. Panel on Wind and Seismic Hazards, May 1973. The subject report is highly pertinent to this ERTS investigation and materials prepared as backup to this report will be used to show areas of seismic hazard within the study areas.

g) Recommendations concerning practical changes in operations, additional investigative effort, correlation of effort and results as related to a maximum utilization of the ERTS system

Because insufficient cloud-free (30% or less) data was acquired during the first year of ERTS-1 operation over the 12 sites proposed in this experiment, we have been unable to complete more than one mosaic (Area 7). It is requested that all data acquired since July 1973 be reviewed for suitability in completing mosaics of other sites than Area 7. All data was cut off to this project at the end of July 1973, the end of the contract year. Needed are 9.5 x 9.5 positive transparencies of bands 4, 5, 6 and 7.

h) A listing by date of any changes in Standing Order Forms

None.

i) ERTS Image Descriptor Forms:

None.

j) Listing by date of any changed Data Request Forms submitted to Goddard Space Flight Center/NDPF during the reporting period

None.

k) Status of Data Collection Platforms

Not Applicable.

INSTITUTO DE INVESTIGACIONES GEOLOGICAS
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SANTIAGO

Santiago, January 29, 1974.

03089

Mr. W.D. Carter
Asst. Program Manager
for Applications Research
EROS Program
U.S. Geological Survey
1925 Newton Square, East
Reston, Virginia 22090
U.S.A.

Dear Doug :

Although I had received your letter of december 19, the box containing the ERTS images that you kindly sent to us, arrived only a few days ago. I am here returning the signed copy of the list of the data and expressing our sincere thanks for such important and valuable material.

After my return from Washington, I discussed your program with several IIG geologists; everybody is very enthusiastic about it and I am sure we will make good use of these images. As you know, we have an hidrogeological program in Northern Chile (superficial and groundwater) and several exploration programs for non metallic and metallic deposits. For this reason, Joaquín Sánchez (hidrogeologist) and Gabriél Pérez & Agustín Gutierrez (economic geologists) will be the persons working with these images. The latter two are compiling all the information on metallic mineral resources, getting all the available structural, geological and mineralogical data, as an aid to program exploration as well as to complete an inventory and to organize the information on our mineral resources. At this moment, there is a student of the Geology Department (Ricardo Sandoval) who is just finishing school and has been very interested in remote sensors; I am trying to get him involved in this work an hope he can concentrate full time on it.

If we could suggest preference areas for continuing work under your ERTS-B program, we would indicate the following :

I.- Tarapacá and Antofagasta provinces (17°30'-27°00 S Lat. 67°00'-70°30'W long) for hidrogeological studies.

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2.- Same area as 1, east of meridian 70°, to complete structural and geological information on economic minerals and geothermal areas.

3.- Area between parallels 30 and 36°, mostly east of meridian 71°, to incorporate more structural information and possibly detect favorable environment for porphyry copper mineralization.

4.- Coast Range between parallels 35° and 41°30'. Although knowledge of geological environment of this region has greatly improved, evaluation of mineral resources needs attention. Iron and chromium deposits exists; these occurrences have encouraged exploration and evaluation programs, especially geochemical studies, which are now under way. This is the area in which we are hoping Kenneth Segerstrom can conduct his test project.

5.- Area between parallels 51° and 56° S. lat. Especially for structural studies and to compile a specific tectonic map for this region.

For the work on the last two regions, we could incorporate interested geologists from the Department of Geology of the University of Chile. Do you think a program like this would be possible? Should I send you a formal letter with this proposition giving more details? I would appreciate your advice.

It was indeed a pleasure seeing you and your family last december, as well as other good old friends in Washington. I keep kind remembrances of my visit there, and I hope we will soon be able to see some of you again here in Chile.

With many thanks to you and your family for making my stay there so pleasant, and with kindest regards to all of you.

Sincerely yours,

José Corvalán Díaz
Director Ejecutivo

Attachment B.

CARTER W.D. (EROS Program, U. S. Geological Survey, Reston, Virginia, USA). Tectolinear Interpretation of an ERTS-1 Mosaic, La Paz Area, Southwest Bolivia, Southeast Peru and Northern Chile.

The La Paz mosaic, composed of all or parts of 22 Earth Resources Technology Satellite (ERTS-1), infrared, band 6 images (0.7-0.8 micrometers) at a scale of 1:1,000,000, has been compiled as a model designed to establish systematic mapping procedures. Such mosaics will assist regional small-scale geologic mapping and mineral resource investigations in lesser developed countries. The mosaic covers an area of 276,000 square kilometers between 16° and 20°S latitude and 66° and 72°W longitude. It is centered over one of the major bends of the Andes Mountains and spans several major mineral resource provinces.

An interpretation overlay of linear features, most of which are considered to be faults, fractures, and folds, indicate that the dominant structural trend is NNW to NW. This trend is probably due largely to orogenic forces resulting from subduction along the western margin of the South American continent. Between La Paz and the Salar de Coipasa, Bolivia, there is also a strong secondary set trending nearly E-W. These may be related to transverse movement between the northern and southern portions of the South American plate. A tertiary set of linears of lesser abundance trends NE. All of the linears are at least 5 kilometers in length, and the longest have been traced for more than 500 kilometers.

The tectolinear overlay is compared with other independent interpretations, existing geologic maps, mineral deposit and oil field location maps, and seismic epicenter maps to determine its utility as an exploration tool.

For submission to the Seventeenth Plenary Meeting of COSPAR, Sao Paulo, Brazil, June 1974.

Attachment C

EROS REPRINT #182

AMERICAN ASTRONAUTICAL SOCIETY

Reprinted from "Space Shuttle Payloads", Volume 30, Science and Technology, 1973, a publication of the American Astronautical Society, Publications Office, P. O. Box 746, Tarzana, California, 91356.

AAS72-158

USE OF SPACE SHUTTLE FOR EARTH RESOURCE MAPPING, INVENTORY AND EVALUATION

William D. Carter +

Man has effectively overcome many of the major problems involved in living and working in a space environment. He must and will use this new knowledge and capability to extend the frontiers of exploration from the Moon and beyond. He must not, however, overlook the possibility of utilizing these new techniques and equipments to improve his knowledge of his major source of supply - Planet Earth.

The Space Shuttle Program can provide several opportunities to improve man's knowledge of the Earth and monitor the environment. It can be used as a bus to place small applications satellites in special orbits and thereby reduce the number of launches and concommitant costs of such vehicles. It can be used as a test-bed for developing and testing new remote sensors to be used in resource inventory mapping and monitoring environmental conditions. It could carry proven instrument packages for use in an operational mode just as aircraft are used today for many purposes. It could service satellites while in orbit by performing simple repairs or replacing parts and thereby increasing their period of usefulness.

These and other potential uses of the Space Shuttle must be carefully weighed in terms of benefits versus costs. We need to learn to utilize man's ability to obtain research data by viewing and reacting immediately to Earth phenomena. Real-time observations from space can be of value in understanding the active Earth phenomena and in the design requirements for future monitoring systems.

ERTS-1, successfully launched into orbit on July 23, 1972, and ERTS-B to follow next year will provide experience in the application of repetitive, multiband photographic images. Skylab will permit scientists to evaluate similar and more sophisticated and specialized remote sensors. These important stepping stones will enable us to provide useful inputs to design of the Space Shuttle system and other follow-on programs.

+Asst. Program Manager for Applications Research, U. S. Geological Survey, EROS Program Office, Washington, D.C.

INTRODUCTION

Concern about our use, waste and contamination of our limited Earth resources has been expressed by many philosophers, conservationists and Earth scientists long before the dawn of the space age. Two that I recall that I believe have had special public impact in the United States were Fairfield Osborn who wrote "Our Plundered Planet" in 1950 and Rachel Carson (1951) author of "The Sea Around Us." They focussed man's attention on our vast but delicate resources and made us conscious of increasing rates of consumption and pollution. Not until very recently have these words by such so-called "prophets of doom" been generally accepted and positive steps taken to conserve our resources and preserve our environment. Perhaps the significance of their forecasts was most dramatically realized after our Apollo astronauts photographed the Earth from lunar orbit. People, for the first time, saw their "Planet Earth" in its true perspective, a blue and white jewel with a thin veneer of atmosphere in the black solitude of space.

Earth scientists have only recently had the opportunity to participate in the benefits of the Space Age. Eight years ago (1964) NASA started its Earth Resources Program by inviting scientists of Federal agencies and universities to participate essentially as contractors to determine how remote sensing devices could be utilized in the observation, mapping and monitoring of Earth phenomena. We started with ground measurements and low flying aircraft using remote sensors capable of recording in the visible and near-visible portions of the spectrum with which we were most familiar. Studies then extended into the thermal infrared and microwave portions of the spectrum. As we learned the applications and limitations of the various instruments, we began to recommend modifications and also moved to higher altitudes.

By 1966, the Interior Department determined that there were sufficient benefits in the program that would help their operation, and they formed the Earth Resources Observation Systems (EROS) Program to provide a concerted, departmental effort aimed at developing operational use of such systems. Eight bureaus within the Department are now fully involved in research to determine where aircraft and spaceborne remote sensors can assist their operations. Similar efforts were begun in the U. S. Department of Agriculture, National Oceanographic and Atmospheric Administration, Department of Defense (Corps of Engineers, U. S. Navy, Defense Mapping Agency), the Department of Transportation and Environmental Protection Agency. Together these agencies have developed a cadre of scientists from all disciplines who are now familiar with the instruments, some of the data handling problems, methods of interpretation and applications of available remote sensors. A number of universities have become involved in teaching courses in remote sensing. State and county resource agencies have also become involved. Many foreign countries, aware of the potential in surveying less-developed areas, have begun their own research programs and some (Brazil, Venezuela, Mexico) have started extensive operational programs.

Views of the Earth from space, provided by vidicon cameras from Nimbus and TIROS weather satellites and the later film pictures by Mercury, Gemini and early Apollo missions convinced many of those scientists that there were definite advantages in synoptic, small scale views of large areas of the Earth's surface. In 1966 the EROS Program and Department of Agriculture sent to NASA their information requirements and participated in drawing up specifications for the first Earth Resources Technology Satellite (ERTS-A). Six years later on July 23, 1972, ERTS-A was launched from the Western Test Range, California, and on gaining a successful nearly circular and polar orbit at an altitude of 560-570 miles, it became designated ERTS-1.

In preparation for this event over 600 experiment proposals from scientists all over the world were sent to NASA for review. Of these, approximately 300 were accepted. Seventy were from scientists of foreign nations and over fifty were from Department of Interior scientists. ERTS-1, an experimental satellite, is truly an international experiment of unparalleled significance. On the other hand, it is but a small early step into the future, and we still have much to learn.

In this paper I would like to describe briefly the pertinent characteristics of ERTS-1 and discuss some of our first observations that result from less than 4 months of data evaluation. I would then like to consider Skylab I and future unmanned satellites which will serve as a prelude to the Space Shuttle. I will conclude by considering Space Shuttle as it is presently defined and comment on ways that may help enhance its utility in the Earth resource area.

ERTS-1 and Early Observations. ERTS-1, built by General Electric, is a modified Nimbus spacecraft weighing about 1 short ton and equal in size to a small Volkswagen beetle. It has two large paddles with solar cells and batteries that provide sufficient power (980 w) to operate a 3-camera return beam vidicon (RBV) image system, a 4-channel multispectral scanner system (MSS), two tape recorders, a telemetry command and control system and an S-Band data transmission system for image data and for monitoring scientific ground stations known as data collection platforms (DCP).

The Return Beam Vidicon (RBV) system, built by RCA, was designed to provide precise geometry and orthographic images for small-scale base maps. Its narrow field of view (FOV = 11°) was selected to minimize Earth curvature and each frame covers 115 miles with an average resolution of about 80 meters. Each of the three cameras is boresighted to the same target and is filtered to a specific range in the visible (green and red) and near-infrared parts of the electromagnetic spectrum. The green band was selected to penetrate water so that the bottoms of shallow lakes and near-shore ocean areas could be observed. The red band was selected to map cultural and natural features without the effects of haze. The infrared band was chosen to map the limits of water bodies, to identify areas of moist ground and to map vegetation.

The Multispectral Scanner System (MSS), built by the Hughes Aircraft Corporation, is a four-band system using common optics and an oscillating mirror. Two of the spectral bands correspond to the green and red bands. It also has two infrared bands (0.6-0.7 and 0.8-1.0 μm) for water and vegetation information. While the system is not as precise as the RBV geometrically, it has higher spectral sensitivity and radiometric accuracy and is amenable to automated digital and analog processing. When any 3 or 4 bands are combined with proper colored filters a false color infrared image can be composed that greatly increases their interpretability.

The Data Collection Platform (DCP) relay capability was built in to provide simultaneous instrumented ground information to ease the interpretation of image data. Ground instruments that are currently being monitored are stream gages, water quality meters, tiltmeters and seismic event counters. The system is limited by the fact that the ground station, satellite, and the data reception station (Fairbanks, Goldstone or Goddard) must be mutually "visible" by radio contact in order to complete the transmission. This constrains the system to operate in areas from Panama north and throughout North America to as far east as Iceland.

In the few months that ERTS-1 has been operating, many tens of thousands of images have been taken and processed. NASA provides data directly to 335 investigators and to participating Federal agencies. The data are also available to the general public through the U. S. Department of Interior EROS Data Center at Sioux Falls, South Dakota, and through the NOAA National Environmental Satellite Service.

In the short time that we have had to study ERTS-1 data, we have found that it meets many of our operational requirements:

1. The RBV images are orthographic and geometrically correct so that small-scale maps (1:250,000 and smaller) can be revised and updated more rapidly. They also provide an adequate base for unmapped regions of the world. Photogrammetric analysis of one ERTS image superimposed on a UTM grid at a scale of 1:1,000,000 shows that it conforms with U. S. national map accuracy standards.

2. The synoptic multiband data has enabled us to better define known large geologic structures such as the major fault zones of California and Alaska.

3. They have also enabled us to define new structural features in Nevada and Oregon.

4. One man (C. E. Cooley) mapped the significant linear features of the Basin and Range Province in Arizona (approximately 2/3 of the state) or 60,000 square miles in 1 week of studying ERTS photographs.

5. We now know that Class I land use mapping can be accomplished by using color composites. Dr. R. Simpson and D. Lindgren, geographers at Dartmouth College, classified land use in the State of Rhode Island in 40 hours of interpretation. Towns containing as few as 7,000 persons could be clearly distinguished and mapped.

6. We also know that we can map surface water bodies such as lakes, rivers, and ponds of less than 40 acres as well as areas of surface soil moisture related to rainfall, irrigation or surficial aquifers. Two MSS images taken in July and August of the high plains in West Texas show a narrow rainstorm track in which small playas are water filled. Similar areas to the north and south were relatively dry. Use of such data should increase our knowledge of the hydrological cycle and increase our ability to make inventories of such rapidly changing phenomena. These data will also aid significantly in the design of networks for monitoring various hydrologic phenomena.

7. With regard to vegetation mapping, color composites displaying vegetative materials as tones of red provide the greatest contrast in forest, shrub, grass and crop determination. Areas of timber harvest are clearly displayed on all types of images and are especially clear in black and white prints in the red portion of the spectrum. Areas of evergreen and deciduous trees can be distinguished and relative vigor of grassy areas (golf courses and parks versus rangelands) have been identified in color composites. Skilled agricultural photointerpreters have distinguished between rice, vineyards, sorghum, cotton and other crops by knowing the crop calendar for the area studied and the date of the available images. The extent, vigor and type of vegetation provides an indication of the quantity of water transpired to the atmosphere. NASA and EROS funded research on remote measurement of transpiration hopefully will provide an important parametric input to eventual terrestrial water models that will enable man to monitor the flux of water through the hydrologic cycle.

8. In Alaska it has been noted that a glacier has extended its length by 6,000 feet since it was mapped last year. "Galloping" glaciers have also been identified in Iceland on the basis of their surface patterns. On the Alaskan coast we have identified the extent of glacial river sediment plumes extending into the Pacific Ocean. Such plumes can mark the location of important detrital minerals or commercial fisheries such as shrimp, salmon, and their respective predators.

9. ERTS-1 also recorded an active and extensive forest fire near Kobuk, a remote area in northern Alaska, in which over 60,000 acres of spruce timber was burned. Another burn scar nearby showed how the vegetation was gradually recovering the area.

These are but a few examples that we have identified in the first three months of ERTS-1 Earth Resource surveys. We await the opportunity to compare these and other features as we collect additional images through the seasons of the year. It is in the area of changing phenomena that the synoptic and repetitive view from space can have its greatest impact.

In the next 10-12 months we will be comparing repetitive data from ERTS-1 to measure temporal changes that occur as the seasons change and as water runoff and other natural phenomena modify the surface of the land. We will also monitor changes that are made by man, such as the creation of new reservoirs, highways, airports and suburbs. I believe that this area of investigation will clearly demonstrate applications benefits that will provide justification for costs expended and those that will need to be made in the development of operational systems.

Now that data is available from the ERTS-1 satellite and its value has been demonstrated, a large number of new data users are anxious to acquire data and enter the program. We anticipate a 50% increase in proposals (800-1000) to enter the ERTS-B program.

Skylab I and Future Systems.

In April 1973 NASA will launch its first Skylab experiment to test man's durability in extended space missions. This mission will also be used to make astronomical investigations outside of the Earth's atmosphere, conduct biomedical experiments, conduct space manufacturing concepts, and test new systems that are designed to study the Earth from space. Skylab will fly in nearly circular orbit at about 250 miles above the Earth and inclined to reach latitudes of 50 degrees north and south of the equator. Three teams of astronauts (3 men per team) will visit the Skylab in succession; the first group for 28 days and the other two for 56 days each.

Several new remote sensor systems are included in what is called the Earth Resource Experiment Package (EREP) which will be tested during the three crew visits. The instruments consist of the following:

1. A six-camera multiband film return system (S-190A) with each camera filtered to a separate band of the visible or near-infrared spectrum. Built by ITEK, it is a cluster of cameras with 6-inch focal length and F/2.8 lenses; the field of view covers 158km square and the pictures are recorded on 70mm film. The spectral bands of 4 cameras range from .5 to .9μm; one camera will have color infrared film and another will carry aerial color film. The ground resolved distance will be 100 feet from 235 nautical miles. Part of the film camera system is the Earth Terrain Camera (S-190B), a modified Lunar Mapping Camera built by Actron with a 24-inch (610 mm) focal length; the field of view covers 109 by 109 km and anticipated resolution of about 3 meters. It will test several film types (black and white, color and color IR) and will be used

on a limited basis in areas where detailed information is required to support investigations and data from lower resolution systems.

2. An Infrared Spectrometer (S-191) covering the range of .4 to 15.5 micrometers will provide solar radiance in the .4 to 2.4 μm region and emitted thermal radiance in 6.2 to 15.5 μm region of soil, rock, vegetation and water spectra of extremely small areas (1 nmi diameter). The instrument is steerable by the astronaut who is provided with a bore-sighted tracking telescope to seek the target, lock on and track a small area as Skylab flies over in a matter of a few seconds.

3. A Multiband Scanner System (S-192) to be flown in Skylab will be similar to that in ERTS-1 but with 13 spectral bands ranging from .40 to 12.5 μm and 10° scan having a ground track swath width of 40 nautical miles. Comparative analyses of bands corresponding to those of ERTS-1 will be conducted and the remaining bands will be studied to determine their increments of information input.

4. The microwave radiometer-scatterometer (S-193) is a passive system providing micro surface roughness and radiance information over open and cloud-covered regions. It operates in the 13.8-14.0 ghz range and covers a 40 nautical mile swath in 6 nautical mile strips at 250 nautical miles. We are especially interested in determining its ability to provide information on the condition and distribution of snow and lake and sea ice.

5. The L-Band radiometer (S-194) operates on a 21 cm wavelength with a band width of 27 MHz. It will record thermal radiation in the microwave (L-Band) region and has absolute antenna temperature to an accuracy of 1°K. The beam width is 15 degrees and has a resolution of 60 nautical mile diameter circle. It will be used primarily for oceanographic applications.

The multipurpose use of Skylab for astronaut medical duration tests, astronomic observations and instrument tests for Earth resource information will provide much greater insight on what should be done in the Space Shuttle program.

Space Shuttle and the Sortie Mode.

The Earth Resources scientific community, is participating with NASA in developing preliminary plans for the Shuttle and the Sortie Mode. During the past month a multi-agency team has been reviewing a two-volume treatise prepared in the NASA workshop by NASA scientists representing the various NASA centers. It is intended that the two-volume work will be supplemented by inputs from other Federal Agencies and presented to a study group drawing from scientists representing universities, industry and state organizations that will meet in the summer of 1973. In this way, NASA hopes to develop a concensus of scientific opinion on the objectives, rationale, hardware and operations of the Shuttle.

OBJECTIVES

1. The Shuttle should be designed to complement rather than duplicate or replace observations that can be made routinely by less expensive unmanned satellites.

2. It should be steerable and capable of providing non-routine information in response to needs as they occur. The shuttle should operate much like the Ames Research Center's Convair 990 which goes on planned extensive missions testing new instrument developments but is, in addition, available to monitor unusual events.

3. The payload capability (65,000 pounds) should be shared between scientific instrument payloads and applications satellites that can be launched from orbit.

4. The Shuttle should be steerable so that it can visit unmanned satellites to replace modular tape recorders, film casettes, circuit boards, power units and orbit adjustors to increase the longevity of such vehicles.

5. An on-board processing capability would enable the Shuttle to transmit only those data that are pertinent to a particular problem or situation thereby reducing the amount of data to be processed and analyzed on the ground.

6. Perhaps the Shuttle could be developed to provide selected real-time observation capability not only in the spacecraft but at receiving stations on the ground. For example, the Shuttle could be tied by radio and TV to the Smithsonian Center for Short-Lived Phenomena. When an event such as earthquake, volcanic eruption, flood or tsunami is reported to the Center, it in turn can notify the Shuttle. The Shuttle will store the latitude/longitude data in its computer and the computer will generate orbital parameters and course correction information to enable passing over the event in the least amount of time. When the site of the event is approached, real-time video monitors in the Shuttle and at the Center could simultaneously review the various imagers (multiband video, near IR, thermal IR and radar imaging in several bands and wavelengths) and select the best for viewing the scene.

7. The Shuttle should be used as a platform for new sensors presently in the theoretical or development stage, such as tuneable lasers for measuring important water quality parameters.

Earth Resource Requirements of the 80's.

1. The Shuttle, in solar or very high inclination orbit, could use side scanning radar to obtain surface information on polar regions during all seasons and weather. Locations of the edge of the ice pack in polar seas, ice leads, and drifting icebergs are important

to world navigation. Periodic monitoring by Sortie missions using passive microwave and/or radar could vastly improve our knowledge of such phenomena.

2. As we gain experience with unmanned satellites, we will quite likely find other areas of the world that are difficult if not impossible to map without cloud cover. Such areas could become mission objectives of the Shuttle Sortie Mode.

3. One of the most common "disaster" events are floods which always occur under foul weather conditions. It would be extremely helpful to be able to obtain data on surface conditions for such events under cloud cover and at night. Because water provides very little to no radar return in the longer wavelength systems, the monitoring ability of active microwave on a shuttle platform should be excellent.

Perhaps the greatest problem in viewing the Earth from space is to "see through" extensive cloud layers. Observations of many disaster situations are accompanied by bad weather or nighttime conditions. Blizzards, hurricanes, volcanic eruptions, floods are but a few examples where a capability to view the Earth is limited by clouds. Passive and active microwave systems currently provide the only methods of penetrating and viewing such phenomena. Single band synthetic aperture radar in space will require more power than is commonly available on satellites. Polypanchromatic multifrequency radars will require still more power. The Shuttle also offers the cpportunity to conduct on-board processing to limit the amount of real-time data that needs to be transmitted to the Earth.

While synoptic views of Earth terrain and ocean phenomena are extremely useful, most of these can be made routinely from unmanned satellites. Skylab and Shuttle should work toward making quantitative measurements where they apply and are appropriate. Man can be used to spot specific localities or targets such as oil slicks, algae blooms or distinctive vegetation, soil or rock types. With a tracking telescope boresighted to a high resolution camera and a spectrometer, a picture of the scene and spectral measurement of the material can be simultaneously obtained.

The proposed Sortie mode of 7 to 30 day missions and orbital inclination to 60 degrees will be adequate to test new instruments as they become available for experimentation. At $10 million per launch, Shuttle should carry at least 5 applications satellites for later launch in orbit in order to offset their cost of launch from the ground. Approximately three Shuttle launches containing 5 satellites each will about equal the total number of NASA launches in 1972. The sortie mode will be inadequate where repetitive Earth resource information is required. This, however, may not be a problem in the 1980's, for we plan to have operational unmanned systems in near polar orbit by that time to satisfy seasonal, monthly and biweekly time requirements. It is also possible that we will have geosynchronous satellites in orbit for

Earth resources that will view phenomena on a daily basis. Surface water distribution, snowpack extent and melting rates, and vegetation changes are but a few examples of phenomena in that category that we wish to monitor.

CONCLUSIONS

In summary, I would like to point out that through NASA's manned space program, from Mercury through Gemini and Apollo, the Nation has gained a very important and useful talent. Not only has man explored the Moon, but the effort has done much to bring the world of nations closer together and stimulate the imagination of youth toward the future. Such stimulation must be encouraged in order for the world to progress. Like the Biblical "Sons with Many Talents" we will only gain the true and maximum benefits from space technology by putting our hard-earned talents to work. We must not let such talents wither on the vine and permit our technical expertise to fade.

It is extremely difficult to project our Earth resource requirements into the next decade when we have only begun to assess the capabilities and benefits of our first Earth Resource Technology Satellite. I am certain, however, that space technology is here to stay and that we must be part of it in order to meet our responsibilities in resource inventory and management. We look forward to future missions of Skylab and ERTS-B as important steps in defining operational automated satellites and instrumentation and missions for the Space Shuttle. Each step will enable us to define objectives and payloads for successive missions and the results of data interpretation will enable us to better assess the real benefits of such technology. I feel confident that such benefits will be realized as we, the scientific community, public and taxpayers, become aware of the "many talents" that are accruing in the Nation's space program.

The Shuttle should complement rather than compete with future operational and experimental Earth resource satellites. Its use for launching and reburbishing unmanned systems is most attractive - if costs of all systems can be reduced significantly or their longevity increased. The Sortie mode can be extremely useful in testing new instrumentation for later operational programs. The Shuttle, however, should not be justified solely on its ability to survey Earth resources, but it must be considered for its broader applications.

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